

transferring the workpiece to the electroplating station using the robotic transfer device;

electroplating copper and the electroplating station to substantially fill the recessed microstructures;

transferring the workpiece to the thermal processing station;

operating the thermal processing station to thermally treat the workpiece including the electroplated copper by establishing a temperature gradient through the workpiece having a maximum temperature less than about 300 degrees Celsius.

184. (New) The method of Claim 183 wherein the temperature gradient through the workpiece has a maximum temperature less than about 250 degrees Celsius.

185. (New) The method of Claim 183 wherein the temperature gradient through the workpiece has a maximum temperature less than about 100 degrees Celsius.

REMARKS

The present Amendment corrects some minor typographical errors in the specification, inserts the serial number of an application previously identified only by attorney docket number; amends claim 40 to broaden its scope; amends claim 69 to refer to copper; and adds new claims 77-185. Upon entry of the present amendment, claims 36-40 and 68-185 will remain in the application.

In the 20 June 2001 Office Action, the Examiner rejected claims 36-40 and 68-76 as obvious over Uzoh US Patent 6,123,825 ("Uzoh"). While the undersigned does not entirely agree with the Examiner's logic in this rejection, Uzoh does not appear to qualify as prior art against this application. Uzoh issued 26 September 2000 on an application filed 2 December 1998. The present application is a continuation of PCT/US99/02504, filed 4 February 1999, which claims priority to 60/087,432, filed 1 June 1998, and 09/018,783, filed 4 February 1998. The undersigned has not yet had an opportunity to carefully review the contents of the provisional application, but it is his understanding that

claims 36-40 and 68-76 find §112 support in provisional application 60/087,432, filed 1 June 1998. As this predates Uzoh's filing date, this reference does not appear to qualify as prior art and the present §103 rejection over Uzoh should be withdrawn.

Applicant believes that upon entry of this Amendment all of the claims in the application will be in condition for allowance, prompt notice of which is courteously solicited. The undersigned is scheduled to meet with Examiner Wyszomierski to discuss this application at 1:00 pm on Tuesday, 9 October. This amendment is being hand-delivered to the Examiner to afford the Examiner an opportunity to review the amendment in advance of the interview if his schedule permits.

Respectfully submitted,

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Enclosures:

Postcard

PTO-1083 (+ copy)

Appendix (Marked-up version of claims)

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APPENDIX – SPECIFICATION MARKED TO SHOW CHANGES

This is a continuation application of International PCT Patent Application No. PCT/US99/02504, designating the US, filed February 4, 1999, entitled METHOD AND APPARATUS FOR LOW TEMPERATURE ANNEALING OF METALLIZATION MICRO-STRUCTURES IN THE PRODUCTION OF A MICROELECTRONIC DEVICE, which claims priority from US Patent Application Serial No. 09/018,783, filed February 4, 1998, and US Patent Application Serial No. 60/087,432 filed June 14, 1998.

The semiconductor wafer with the seed layer 425 is subject to a subsequent electrochemical copper deposition process. The electrochemical copper deposition process is executed so as to form numerous nucleation sites for the copper deposition to thereby form grain sizes that are substantially smaller than the characteristic dimensions of the via 420 and trench 415. An exemplary structure having such characteristics is illustrated in Fig. 2E ~~4E~~ wherein layer 440 is a layer of copper metallization that has been deposited using an electrochemical deposition process.

A comparison between Figs. 2E and 2F ~~4E and 4F~~ reveals that an increase in the grain size of the copper layer 440 has taken place. Traditionally, the change in the grain size has been forced through an annealing process. In such an annealing process, the wafer is subject to an elevated temperature that is substantially above the ambient temperature conditions normally found in a clean room. For example, such annealing usually takes place in a furnace having a temperature generally around or slightly below 400 degrees Celsius, or about half of the melting temperature of the electrodeposited copper. Annealing steps are normally performed at a temperature of at least 25 percent of the melting point temperature of the material as measured on an absolute temperature scale. As such, a separate annealing step is performed on the wafer using a separate piece of capital equipment. Such an annealing step is usually performed for each layer of metallization that is deposited on the wafer. These additional steps increase the cost of

manufacturing devices from the wafer and, further, provide yet another step in which the wafer may be mishandled, contaminated or otherwise damaged.

The electrochemical plating solution may be Enthone-OMI Cu Bath M Make-up Solution having 67 g/l of CuSO₄~~CuSO₄~~, 170 g/l of H₂SO₄~~H₂SO₄~~, and 70 ppm of HCl. The additive solutions utilized may be Enthone-OMI Cu Bath M-D (6.4 ml/l - make-up) and Enthone-OMI Cu Bath M LO 70/30 Special (1.6 ml/l - make-up). The flow rate through the cup 25 of this solution may be approximately 1.0 - 10 GPM (preferably 5.5 GPM) and the plating temperature may be between about 10-40 degrees Celsius (preferably 25 degrees Celsius). The plating bath could alternatively contain any of a number of additives from manufacturers such as Shipley (Electroposit 1100), Lea Ronal (Copper Gleam PPR), or polyethylene glycol (PEG). An alkaline plating bath suitable for electroplating microelectronic components is set forth in co-pending provisional patent application U.S.S.N. 60/085,675, filed 15 May 1998 and _____, entitled "PROCESS AND PLATING SOLUTION FOR ELECTROPLATING A COPPER METALLIZATION LAYER ONTO A WORKPIECE" (~~Attorney Docket No. SEM4492PO250US; Corporate Docket No. P98-0039~~) which is hereby incorporated by reference.

APPENDIX – CLAIMS
MARKED TO SHOW CHANGES

40. (Twice Amended) A method for reducing voids in a metal material that has been electrolytically deposited into recessed microstructures defined on a surface of a microelectronic workpiece comprising:

electrolytically depositing a metal to substantially fill recessed sub-micron structures on the surface of the workpiece; and then

subjecting the workpiece to an annealing process ~~in which the workpiece is subject to generate~~ a controlled temperature gradient in which the temperature decreases along a cross-section of the workpiece in a direction that is toward the surface in which the recessed sub-micron structures are formed.

69. (Amended) A method for reducing voids in ~~a-copper~~ metal material that has been ~~electrochemically-electrolytically~~ deposited into recessed microstructures defined in a surface of a microelectronic workpiece comprising:

~~electrochemically-electrolytically~~ depositing ~~a-copper~~ metal to substantially fill sub-micron recessed structures in the surface of the workpiece and

then subjecting the surface of the workpiece to an annealing process at a temperature that is at or below about ~~250 to~~ 300 degrees Celsius.